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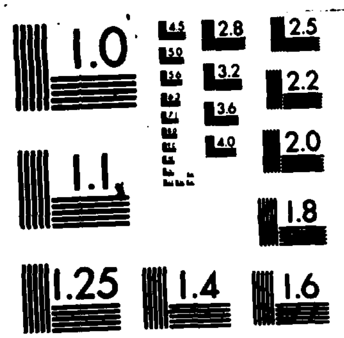
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US Army Corps
of Engineers

AD A138369

MISCELLANEOUS PAPER CERC-83-9

HANDHELD CALCULATOR ALGORITHMS FOR COASTAL ENGINEERING

Report 3

by

Julie L. Dean, Todd L. Walton, Jr.

Coastal Engineering Research Center
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

December 1983

Report 3 of a Series

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Prepared for Office, Chief of Engineers, U. S. Army
Washington, D. C. 20314

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Peak spectral period
Significant wave height
Spectral wave height

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

> This is the third in a series of reports providing handheld calculator algorithms for use in coastal engineering. The first and second reports in this series were published as Coastal Engineering Technical Aids (CETA's) and are available from the U. S. Army Engineer Waterways Experiment Station Technical Report Distribution Center, Vicksburg, Miss. Of these, CETA 82-1 presents a set of six algorithms for programs useful in performing certain wave -

(Continued)

1

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20. ABSTRACT (Continued).

transformation and wave generation calculations with both the Texas Instruments TI-59 (Algebraic Operating System (AOS) notation) and the Hewlett-Packard HP-67 (Reverse Polish Notation (RPN)); CETA 82-4 presents the same six algorithms for use on the HP-41CV (RPN).

The present report provides algorithms for three calculator programs that forecast gravity water waves in deep and shallow water. Two programs use the Joint North Sea Wave Project (JONSWAP) shallow- and deepwater wave forecasting equations as presented in the Coastal Engineering Research Center's Shore Protection Manual (revised edition to be published in 1984). The third program uses equations to predict a depth-limited significant wave height. The programs are intended for use with the HP-41CV.

PREFACE

This report was prepared as part of the Littoral Data Collection Methods and Their Engineering Application Research Work Unit, Shore Protection and Restoration Program, Coastal Engineering Area of Civil Works Research and Development. Technical Monitors from the Office, Chief of Engineers for the Coastal Engineering Area are Mr. John H. Lockhart, Jr., and Mr. John Housley.

This work was accomplished during the period 1 July 1983 through 30 December 1983 by The Coastal Engineering Research Center (CERC) of the U. S. Army Engineer Waterways Experiment Station (WES), under the general supervision of Dr. Robert W. Whalin, Chief, CERC; Dr. Lewis E. Link, Assistant Chief, CERC; Dr. Dennis R. Smith and Mr. Fred E. Canfield, Acting Chiefs, Engineering Development Division; and Mr. Thomas W. Richardson, Chief, Coastal Structures and Evaluation Branch. This report was prepared by Ms. Julie L. Dean, Engineering Assistant, and Dr. Todd L. Walton, Jr., Research Hydraulic Engineer.

Commander and Director of WES during the publication of this report was COL Tilford C. Creel, CE. Mr. F. R. Brown was Technical Director.

CONTENTS

CONVERSION FACTORS, INCH-POUND TO METRIC (SI) UNITS OF MEASUREMENTS

Inch-pound units of measurement used in this report have been converted to metric (SI) units as follows:

Multiply	By	To Obtain
feet	0.3048	meters
miles (U. S. statute)	1.609347	kilometers
miles per hour (international)	0.44704	meters per second

HANDHELD CALCULATOR ALGORITHMS FOR COASTAL ENGINEERING

Report 3

PART I: INTRODUCTION

1. The advent of the handheld programmable calculator has led to the development of numerous programs in various fields of engineering and science. Coastal engineering is no exception. This report provides three programs to forecast waves in deep and shallow water. Two programs use the Joint North Sea Wave Project (JONSWAP) wave forecasting equations for deep and shallow water as presented in the Shore Protection Manual (U. S. Army Engineer Waterways Experiment Station Coastal Engineering Research Center (CERC), in preparation, 1984). The third program predicts a depth-limited significant wave height using a spectral approach (Vincent 1982, Thompson and Vincent 1983).

2. The three programs presented herein are versions of Reverse Polish Notation (RPN) logic suitable for use on HP-41CV programmable calculators with or without accessory printer. Each program is documented, assumptions are briefly described, and references to more detailed presentations of the theory are given.

3. Each of the RPN programs incorporates HP-41 compatible-print routines which print and label all input and output parameters. The user has only to enter the input parameters and the results are automatically computed and printed. Since the printing routines increase program length by as much as 25 percent, use of a magnetic card for permanent program storage is recommended. The print steps do not need to be deleted if a printer is unavailable.

PART II: PROGRAMS

4. Three programs (103R-Rev, 106R, and 107R) are presented in this report. Program 103R-Rev is a revised version of Program 103R (Walton, Birkemeier, and Weggel 1982) and is being published herein with slight changes for consistency.

5. Program 103R-Rev forecasts significant wave height and spectral peak period in shallow water, using JONSWAP wave forecasting equations of the Shore Protection Manual (CERC, in preparation, 1984). Program 106R forecasts the deepwater significant wave height and spectral peak period for fetch-limited, duration-limited, and fully developed sea cases in deep water. The JONSWAP forecasting equations used are presented in Table 3-2 of the Shore Protection Manual (CERC, in preparation, 1984). Program 107R calculates a depth-limited significant wave height based on an estimate of the peak frequency of shallow-water storm wave spectra. Equation (14) from Vincent (1982) and equation (5) from Thompson and Vincent (1983) are used.

6. Each program allows either English or metric input and output. Program listings are annotated, making it possible to follow the logic of the algorithm and to make modifications if desired.

7. There are undoubtedly many calculator programs not included here that have been developed on coastal engineering subjects. Practicing engineers who would like to share such programs (in either AOS or RPN) with other users are encouraged to submit them to the CERC. If the response is great enough, additional reports presenting the programs will be prepared. Comments, programs, or suggestions for programs should be sent to:

Commander and Director
U. S. Army Engineer Waterways Experiment Station
ATTN: Coastal Structures and Evaluation Branch, CERC
P. O. Box 631
Vicksburg, Mississippi 39180

8. These and future programs will generally correspond to the following numbering scheme:

Miscellaneous	0-99	Beaches	500-699
Waves and currents	100-299	Geology	700-899
Inlets	300-499	Structures	900-1099

9. In general, the documentation of programs submitted should be in a format paralleling that of the programs presented in this report. A blank set of forms which can be reproduced is included in Appendix A

Program Description

Program Title	103R-41CV-REV: JONSWAP Shallow-Water Wave Forecasting Equations, Revised (RPN Logic)
Name	Todd L. Walton, Jr. — **Date** 7/83
Address	Coastal Engineering Research Center
City	Waterways Experiment Station — Vicksburg — **State** MS — **Zip Code** 39180

Program Description, Equations, Variables, etc.

This algorithm computes the wave height, H, wave period, T, and minimum duration, t, from input values of the water depth, d, fetch length, F, and adjusted windspeed, U_A using equations (3-39), (3-40), and (3-41) of the Shore Protection Manual (CERC, in preparation, 1984). Equations (3-39) and 3-40) are for constant depth and unlimited wind duration. Wave height and period in this algorithm are significant wave height and period. Algorithm uses English or metric system of units.

REFERENCE

U. S. Army Engineers, Coastal Engineering Research Center, Shore Protection Manual, Chapter 3 (in preparation).

Operating Limits and Warnings

User Instructions

103R-41CV-REV: JONSWAP Shallow-Water Wave Forecasting Equations, Revised (RPN Logic)

SIZE: 010

STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1	LOAD PROGRAM (FOCAST)		[XEQ]"FOCAST"	E OR M?
2	CHOOSE ENGLISH OR METRIC UNITS		E or M, [R/S]	U_A?
3	ENTER ADJUSTED WINDSPEED			
	(miles per hour or meters per sec)	U_A	[R/S]	FETCH?
4	ENTER FETCH (feet or km)	F	[R/S]	DEPTH?
5	ENTER DEPTH (feet or m)	d	[R/S]	
6	READ SIGNIFICANT WAVE			
	HEIGHT (feet or meters)			H
7	READ SIGNIFICANT WAVE			
	PERIOD (sec)			T
8	READ MINIMUM DURATION			
	(hours)			TIME
	Example Problem:			
	U_A = 50 mph = 22 m/sec			
	F = 80,000 ft. = 24.4 km			
	d = 35 ft. = 11 m.			

```
SHALLOW FORECASTING          SHALLOW FORECASTING
ENGLISH UNITS                METRIC UNITS
UA=                          UA=
        50.0000 ***                 22.0000 ***
FETCH=                       FETCH=
    80,000.0000 ***                 24.4000 ***
DEPTH=                       DEPTH=
        35.0000 ***                 11.0000 ***
H=4.9795                     H=1.4922
T=4.[illegible]              T=4.4044
TIME=[illegible].5895        TIME=1.6155
```

Program Listing

STEP	KEY ENTRY	KEY CODE	COMMENTS
01	♦LBL "FOCAST"		
02	"SHALLOW FORECAS"		
03	"TING"		
04	AVIEW		
05	♦LBL 05		
06	"E OR M ?"		
07	AON		
08	TONE 1		
09	PROMPT		
10	AOFF		
11	ASTO Y		
12	CLA		
13	"M"		
14	ASTO X		
15	CLA		
16	X=Y?		
17	GTO 01		
18	"ENGLISH UNITS"		
19	AVIEW		
20	32.2		
21	STO 09		$g_{English} \rightarrow R_{09}$
22	1.47		
23	STO 07		Eng. Conversion → R_{07}
24	1.0		
25	STO 01		Eng. Conversion → R_{01}
26	GTO 02		
27	♦LBL 01		
28	"METRIC UNITS"		
29	AVIEW		
30	9.81		
31	STO 09		$g_{Metric} \rightarrow R_{09}$
32	1.0		
33	STO 07		Metric Conversion → R_{07}
34	1000		
35	STO 01		Metric Conversion → R_{01}
36	♦LBL 02		
37	"UA?"		
38	TONE 2		
39	PROMPT		
40	"UA="		
41	FS? 55		
42	XEQ 04		
43	STO 03		$U_A \rightarrow R_{03}$
44	"FETCH?"		
45	TONE 3		
46	PROMPT		
47	"FETCH="		
48	FS? 55		
49	XEQ 04		
50	STO 05		$F \rightarrow R_{05}$
51	"DEPTH?"		
52	TONE 4		
53	PROMPT		
54	"DEPTH="		
55	FS? 55		
56	XEQ 04		
57	STO 06		$d \rightarrow R_{06}$
58	RCL 03		
59	RCL 07		

STEP	KEY ENTRY	KEY CODE	COMMENTS
60	*		
61	STO 07		$U_{A_{converted}} \rightarrow R_{07}$
62	RCL 09		
63	RCL 07		
64	X↑2		
65	/		
66	STO 08		$g/U_A^2 \rightarrow R_{08}$
67	RCL 06		
68	*		
69	STO 00		$gd/U_A^2 \rightarrow R_{00}$
70	RCL 03		
71	RCL 01		
72	*		
73	RCL 05		
74	*		
75	STO 01		$\frac{gF}{U_A^2} \rightarrow R_{01}$
76	RCL 00		
77	.75		
78	Y↑X		
79	.53		
80	*		
81	XEQ 03		
82	STO 04		$\tanh\left[0.53\left(\frac{gd}{U_A^2}\right)^{0.75}\right] \rightarrow R_{04}$
83	RCL 01		
84	SQRT		
85	.00565		
86	*		
87	RCL 04		
88	/		
89	XEQ 03		$\tanh\left[\frac{0.00565}{R_{04}}\left(\frac{gF}{U_A^2}\right)^{0.5}\right]$
90	RCL 04		
91	*		
92	.283		
93	*		
94	RCL 08		
95	/		
96	"H="		H displayed.
97	ARCL X		
98	AVIEW		
99	TONE 7		
100	RCL 00		
101	.375		
102	Y↑X		
103	.833		
104	*		
105	XEQ 03		$\tanh\left[0.833\left(\frac{gd}{U_A^2}\right)^{0.375}\right]$
106	STO 04		$\rightarrow R_{04}$
107	RCL 01		
108	.333		
109	Y↑X		
110	.0379		
111	*		
112	RCL 04		
113	/		
114	XEQ 03		$\tanh\left[\frac{0.0379}{R_{04}}\left(\frac{gF}{U_A^2}\right)^{0.333}\right]$
115	RCL 04		
116	*		
117	7.54		
118	*		

103R-41CV-REV.-3

STEP	KEY ENTRY	KEY CODE	COMMENTS
119	RCL 08		
120	/		
121	RCL 07		
122	/		
123	"T="		Tdisplayed
124	ARCL X		
125	AVIEW		
126	TONE 8		
127	RCL 09		
128	*		
129	RCL 07		
130	/		
131	2.333		
132	Y↑X		
133	537		
134	*		
135	RCL 07		
136	*		
137	RCL 09		
138			
139	3600		
140	/		
141	"TIME="		Time displayed
142	ARCL Y		
143	AVIEW		
144	TONE 9		
145	STOP		
146	GTO 05		
147	♦LBL 03		
148	STO 02		
149	E↑X		
150	RCL 02		
151	CHS		
152	E↑X		
153	-		
154	RCL 02		
155	E↑X		
156	RCL 02		
157	CHS		
158	E↑X		
159	+		
160			
161	RTN		
162	♦LBL 04		
163	PRA		
164	PRX		
165	RTN		
166	END		

103R-41CV-REV.-4

Program Description

Program Title	106R-41CV: JONSWAP Deepwater Wave Forecasting Equations (RPN Logic)
Name	Julie L. Dean — **Date** 7/83
Address	Coastal Engineering Research Center
City	Vicksburg — **State** MS — **Zip Code** 39180

Program Description, Equations, Variables, etc.

This program takes the fetch length, F, adjusted windspeed, U_A, and duration, t, as input values and calculates the deepwater spectral wave height, H_{MO}, and the peak spectral period, T_m, for fetch-limited, duration-limited, and fully developed sea cases in deep water. The equations used are presented in the Shore Protection Manual, Table 3-20. The algorithm uses either English or metric units.

REFERENCE

U. S. Army Engineer Waterways Experiment Station, Shore Protection Manual, Chapter 3 (in preparation).

Operating Limits and Warnings

106R-41CV-1

User Instructions

106R-41CV: JONSWAP Deepwater Wave Forecasting Equations (RPN Logic)

SIZE: 010

STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1	LOAD PROGRAM (DEEPFOR)		[XEQ] "DEEPFOR"	E OR M?
2	CHOOSE ENGLISH OR METRIC UNITS		E or M, [R/S]	FETCH?
3	ENTER FETCH (miles or kilometers)	F	[R/S]	UA?
4	ENTER ADJUSTED WINDSPEED			
	(miles/hr or meters/sec)	U_A	[R/S]	DURATION?
5	ENTER DURATION (hours)	t	[R/S]	
6	FETCH-LIMITED CASE			
	READ H_{MO}, SPECTRAL WAVE HT.			H_{MO} (ft. or m.)
	READ T_M, PEAK SPECTRAL PERIOD			T_M (sec.)
7	DURATION-LIMITED CASE			
	READ H_{MO}, SPECTRAL WAVE HT.			H_{MO} (ft. or m.)
	READ T_M, PEAK SPECTRAL PERIOD			T_M (sec.)
8	FULLY DEVELOPED CASE			
	READ H_{MO}, SPECTRAL WAVE HT.			H_{MO} (ft. or m.)
	READ T_M, PEAK SPECTRAL PERIOD			T_M (sec)
9	PRESS R/S TO ENTER A NEW PROBLEM			

Example Problem:

F = 9.21 miles = 14.83 km

U_A = 46.05 miles/hr = 20.59 meters/sec

t = 20 hours

```
DEEPWATER FORECASTING
ENGLISH UNITS
FETCH=
          9.2100    ***
UA=
         46.0500    ***
DURATION=
         20.0000    ***

FETCH LIMITED
HMO=4.2065
TM=4.1999

DURATION LIMITED
HMO=23.9700
TM=13.3986

FULLY DEVELOPED
HMO=34.4536
TM=17.0661
```

```
DEEPWATER FORECASTING
METRIC UNITS
FETCH=
         14.8300    ***
UA=
         20.5900    ***
DURATION=
         20.0000    ***

FETCH LIMITED
HMO=1.2814
TM=4.2006

DURATION LIMITED
HMO=7.2964
TM=13.3953

FULLY DEVELOPED
HMO=10.5228
TM=17.0897
```

106R-41CV-2

PROGRAM DEEPFOR FLOWCHART

START PROGRAM
XEQ "DEEPFOR"

↓

ENTER AND STORE
VARIABLES

↓

COMPUTE: FETCH LIMITED

$$H_{mo} = 1.6\text{x}10^{-3} \left(\frac{gF}{U_A{}^2}\right)^{\frac{1}{2}} \frac{U_A{}^2}{g}$$

$$T_m = 2.857\text{x}10^{-1} \left(\frac{gF}{U_A{}^2}\right)^{1/3} \frac{U_A}{g}$$

↓

COMPUTE: DURATION LIMITED

$$F_{eff} = \frac{U_A{}^2}{g} \left(\frac{gt}{(6.88\text{x}10^1)U_A}\right)^{3/2}$$

$$H_{mo} = 1.6\text{x}10^{-3} \left(\frac{gF_{eff}}{U_A{}^2}\right)^{\frac{1}{2}} \frac{U_A{}^2}{g}$$

$$T_m = 2.857\text{x}10^{-1} \left(\frac{gF_{eff}}{U_A{}^2}\right)^{1/3} \frac{U_A}{g}$$

↓

COMPUTE: FULLY DEVELOPED

$$H_{mo} = 2.433\text{x}10^{-1} \frac{U_A{}^2}{g}$$

$$T_m = \frac{8.134\ U_A}{g}$$

Program Listing

STEP	KEY ENTRY	KEY CODE	COMMENTS
01	♦LBL "DEEPFOR"		
02	"DEEPWATER FOREC"		
03	"⊦ASTING"		
04	AVIEW		
05	♦LBL 04		
06	"E OR M?"		
07	AON		
08	TONE 2		
09	PROMPT		
10	AOFF		
11	ASTO Y		
12	CLA		
13	"M"		
14	ASTO X		
15	CLA		
16	X=Y?		
17	GTO 01		
18	"ENGLISH UNITS"		
19	AVIEW		
20	3.01 E-2	(English)	$3.01\times10^{-2} = \frac{H_{M0}}{U_A F^{.5}} \to R_{04}$
21	STO 04		
22	5.59 E-1		$5.59\times10^{-1} = \frac{T_M}{(U_A F)^{1/3}} \to R_{05}$
23	STO 05		
24	2.1128 E-2		$2.1128\times10^{-2} = \frac{H_{M0}}{U_A^{1.25} t^{.75}} \to R_{06}$
25	STO 06		
26	4.415 E-1		$4.415\times10^{-1} = \frac{T_M}{U_A^{.5} t^{.5}} \to R_{07}$
27	STO 07		
28	1.625 E-2		$1.625\times10^{-2} = \frac{H_{M0}}{U_A^2} \to R_{08}$
29	STO 08		
30	3.706 E-1		$3.706\times10^{-1} = \frac{T_M}{U_A} \to R_{09}$
31	STO 09		
32	GTO 02		
33	♦LBL 01		
34	"METRIC UNITS"		
35	AVIEW	(Metric)	
36	1.616 E-2		$1.616\times10^{-2} = \frac{H_{M0}}{U_A F^{.5}} \to R_{04}$
37	STO 04		
38	6.238 E-1		$6.238\times10^{-1} = \frac{T_M}{(U_A F)^{1/3}} \to R_{05}$
39	STO 05		
40	1.759 E-2		$1.759\times10^{-2} = \frac{H_{M0}}{U_A^{1.25} t^{.75}} \to R_{06}$
41	STO 06		
42	6.601 E-1		$6.601\times10^{-1} = \frac{T_M}{U_A^{.5} t^{.5}} \to R_{07}$
43	STO 07		
44	2.4821 E-2		$2.4821\times10^{-2} = \frac{H_{M0}}{U_A^2} \to R_{08}$
45	STO 08		
46	8.3 E-1		$8.3\times10^{-1} = \frac{T_M}{U_A} \to R_{09}$
47	STO 09		
48	♦LBL 02		
49	"FETCH?"		
50	TONE 3		
51	PROMPT		
52	"FETCH="		
53	FS? 55		
54	XEQ 03		
55	STO 01		$F \to R_{01}$
56	"UA?"		
57	TONE 4		
58	PROMPT		
59	"UA="		
60	FS? 55		
61	XEQ 03		
62	STO 02		$U_A \to R_{02}$
63	"DURATION?"		
64	TONE 5		
65	PROMPT		
66	"DURATION="		
67	FS? 55		
68	XEQ 03		
69	STO 03		$t \to R_{03}$
70	ADV		
71	"FETCH LIMITED"		
72	AVIEW		
73	RCL 01		
74	SQRT		
75	RCL 02		
76	*		
77	RCL 04		
78	*		$H_{M0} = R_{04} \cdot U_A F^{0.5}$
79	"HMO="		
80	ARCL X		
81	AVIEW		
82	TONE 4		
83	RCL 02		
84	RCL 01		
85	*		
86	3		
87	1/X		
88	Y↑X		
89	RCL 05		
90	*		
91	"TM="		$T_M = R_{05}(U_A F)^{1/3}$
92	ARCL X		
93	AVIEW		
94	TONE 5		
95	ADV		
96	"DURATION LIMITE"		
97	"⊦D"		
98	AVIEW		
99	RCL 03		
100	.75		
101	Y↑X		
102	RCL 02		
103	1.25		
104	Y↑X		
105	*		
106	RCL 06		
107	*		
108	"HMO="		$H_{M0} = R_{06} U_A^{1.25} t^{0.75}$
109	ARCL X		
110	AVIEW		
111	TONE 6		
112	RCL 03		
113	RCL 02		
114	*		
115	SQRT		
116	RCL 07		

106R-41CV-4

STEP	KEY ENTRY	KEY CODE	COMMENTS
117	*		
118	"TM="		$T_M = R_{07} U_A^{0.5} t^{0.5}$
119	ARCL X		
120	AVIEW		
121	TONE 7		
122	ADV		
123	"FULLY DEVELOPED"		
124	AVIEW		
125	RCL 02		
126	X↑2		
127	RCL 08		
128	*		
129	"HMO="		$H_{M0} = R_{08} U_A^2$
130	ARCL X		
131	AVIEW		
132	TONE 8		
133	RCL 02		
134	RCL 09		
135	*		
136	"TM="		$T_M = R_{09} U_A$
137	ARCL X		
138	AVIEW		
139	TONE 9		
140	STOP		
141	GTO 04		
142	♦LBL 03		
143	PRA		
144	PRX		
145	RTN		
146	END		

106R-41CV-5

Program Description

Program Title	107R-41CV: Depth-Limited Significant Wave Height (RPN Logic)		
Name	Julie L. Dean	**Date**	4/83
Address	Coastal Engineering Research Center		
City	Vicksburg	**State** MS	**Zip Code** 39180

Program Description, Equations, Variables, etc.

This program calculates a depth-limited significant wave height as given by equation (14) from Vincent (1982) and equation (5) from Thompson and Vincent (1983), given depth, peak frequency of the wave spectrum, and Phillip's equilibrium coefficient. The low cut-off frequency is 0.80 fp. The upper cut-off frequency is 2.0 fp, where fp is the peak frequency. Simpson's Rule is used to numerically integrate the frequency spectrum. The algorithm uses either English or metric units.

REFERENCES

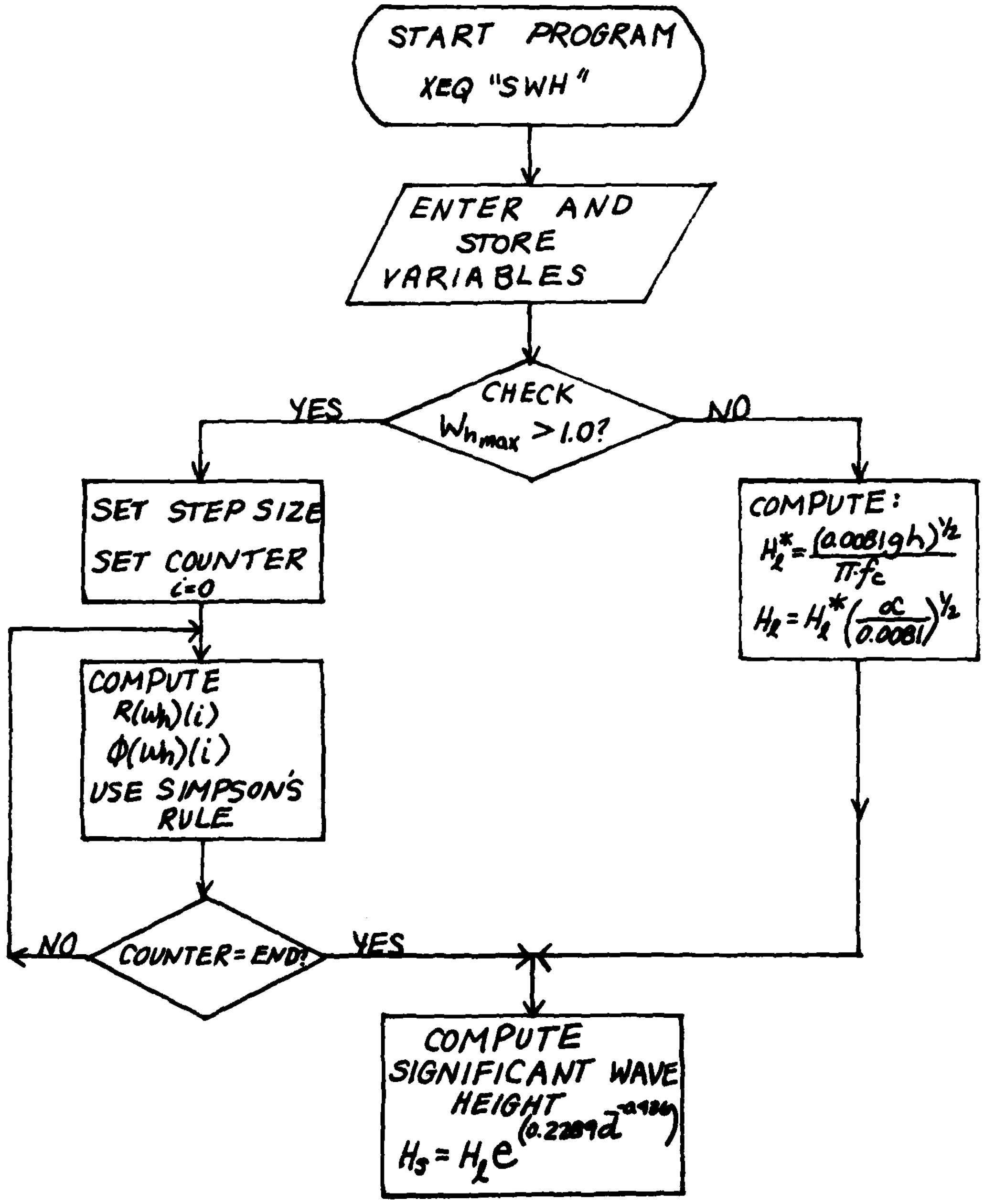
Vincent, C. L. 1982. "Depth-Limited Significant Wave Height: A Spectral Approach," Coastal Engineering Research Center Technical Report 82-3, U. S. Army Corps of Engineers Coastal Engineering Research Center, August 1982.

Thompson, E. F., and Vincent, C. L. "Significant Wave Height for Shallow Water Design," (submitted to ASCE for publication, June 1983).

Vincent, C. L. "A Method for Estimating Depth-Limited Wave Energy," Technical Aid No. 81-16, U. S. Army Corps of Engineers Coastal Engineering Research Center, November 1981.

Operating Limits and Warnings

Program SWH Flowchart



107R-41CV-2

METHODOLOGY USED IN THE PROGRAM

Equations	Reference
Find $\omega_{h_{max}}$:	
$\omega_{h_{max}} = \omega\sqrt{\frac{h}{g}}$,	Equation (6): Vincent 1982
$\omega = 2\pi f$	
and $f = 2 \cdot fp$	
If $\omega_{h_{max}} \leq 1.0$	
1. $H_{\ell}^{*} = \frac{1}{\pi}(\alpha g h)^{\frac{1}{2}} f_c^{-1}$	Equation (16): Vincent 1982
2. $H_{\ell} = H_{\ell}^{*}\left(\frac{\alpha}{0.0081}\right)^{\frac{1}{2}}$	Equation (15): Vincent 1982
3. $H_s = H_{\ell}\exp\left(0.02289\bar{d}^{-0.43642}\right)$	Equation (5): Thompson and Vincent 1983
Where $\bar{d} = \frac{h}{gT_p^2} = \frac{df_p^2}{g}$	
If $\omega_{h_{max}} > 1.0$	
1. $R(\omega_h)\tanh(\omega_h^2 R(\omega_h)) = 1$	Equation (7): Vincent 1982
2. $\phi(\omega_h) = R(\omega_h)^{-2}\left[1 + \frac{2\omega_h^2 R(\omega_h)}{\sinh(2\omega_h^2 R(\omega_h))}\right]^{-1}$	Equation (5): Vincent 1982
3. $E_h = \int_{0.8fp}^{2.0fp} \frac{\alpha g^2 f^{-5}\phi(\omega_h)}{(2\pi)^4}\, df$	Equation (13): Vincent 1982
Simpson's Rule is used to numerically integrate Step 3	
$f(x)dx = \frac{h}{3}\left\{y_o + 4y_1 + 2y_2 + \ldots + 4y_{i-1} + y_i\right\}$	
4. $H_{\ell}^{*} = 4.0\,(E_h)^{\frac{1}{2}}$	Equation (14): Vincent 1982
5. $H_{\ell} = H_{\ell}^{*}\left(\frac{\alpha}{0.0081}\right)^{\frac{1}{2}}$	Equation (15): Vincent 1982
6. $H_s = H_{\ell}\exp\left(0.02289\bar{d}^{-0.43642}\right)$	Equation (5): Thompson and Vincent 1983
$\bar{d} = \frac{h}{gT_p^2} = \frac{df_p^2}{g}$	

User Instructions

107R-41CV: JONSWAP Depth-Limited Significant Wave Height

SIZE: 033

STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1	LOAD PROGRAM (SWH)		[XEQ] "SWH"	E OR M?
2	CHOOSE ENGLISH OR METRIC UNITS		E or M, [R/S]	DEPTH?
3	ENTER DEPTH (feet or meters)	d	[R/S]	PEAK F?
4	ENTER SPECTRAL PEAK			
	FREQUENCY	f_p	[R/S]	ALPHA?
5	ENTER PHILLIP'S EQUILIBRIUM			
	COEFFICENT	α	[R/S]	
6	READ SIGNIFICANT WAVE			
	HEIGHT (feet or meters)			H_S =
	Note: With 4 integration increments, the program takes			
	2 minutes to run.			

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User Instructions

Example Problems

1. input: $d = 3 ft. = 0.9144 m.$ $f_p = 0.0875$ $\alpha = 0.0101$

```
SIGNIFICANT WAVE HT.          SIGNIFICANT WAVE HT.
ENGLISH UNITS                 METRIC UNITS
DEPTH=                        DEPTH=
      3.000000000   ***             0.914400000   ***
PEAK F=                       PEAK F=
      0.087500000   ***             0.087500000   ***
ALPHA=                        ALPHA=
      0.010100000   ***             0.010100000   ***
HS=7.712829318                HS=2.350066497
  Hl= 4.491602737   ***         Hl= 1.368722437   ***
```

2. input: $d = 30 ft. = 9.144 m.$ $f_p = 0.0875$ $\alpha = 0.0101$

```
SIGNIFICANT WAVE HT.          SIGNIFICANT WAVE HT.
ENGLISH UNITS                 METRIC UNITS
DEPTH=                        DEPTH=
      30.00000000   ***             9.144000000   ***
PEAK F=                       PEAK F=
      0.087500000   ***             0.087500000   ***
ALPHA=                        ALPHA=
      0.010100000   ***             0.010100000   ***
HS=15.90217827                HS=4.844781100
  Hl= 13.04655079   ***         Hl= 3.974940968   ***
```

3. input: $d = 10 ft. = 3.048 m.$ $f_p = 0.1875$ $\alpha = 0.02152$

```
SIGNIFICANT WAVE HT.          SIGNIFICANT WAVE HT.
ENGLISH UNITS                 METRIC UNITS
DEPTH=                        DEPTH=
      10.00000000   ***             3.048000000   ***
PEAK F=                       PEAK F=
      0.187500000   ***             0.187500000   ***
ALPHA=                        ALPHA=
      0.021520890   ***             0.021520896   ***
HS=6.004890523                HS=1.82950280[illegible]
  Hl= 5.094688089   ***         Hl= 1.552244259   ***
```

4. input: $d = 15 ft. = 4.572 m.$ $f_p = 0.1875$ $\alpha = 0.02152$

```
SIGNIFICANT WAVE HT.          SIGNIFICANT WAVE HT.
ENGLISH UNITS                 METRIC UNITS
DEPTH=                        DEPTH=
      15.00000000   ***             4.572000000   ***
PEAK F=                       PEAK F=
      0.187500000   ***             0.187500000   ***
ALPHA=                        ALPHA=
      0.021520890   ***             0.021520890   ***
HS=7.060469425                HS=2.154519853
  Hl= 6.152105461   ***         Hl= 1.877382756   ***
```

Example problems 1 and 2 correspond to example problem #1 of Reference (3). Example problems 3 and 4 correspond to example problem #2 of Reference (3).

Values of H_l (stored in R_{08}) have been printed out for comparison with the example problems of Reference (3). These program values differ from Reference (3) values because the integration limits in this program are from $0.8 f_p$ to $2.0 f_p$ and the limits used in the Reference (3) are from $0.9 f_p$ to 1 Hz.

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Program Listing

STEP	KEY ENTRY	KEY CODE	COMMENTS
01	♦LBL "SWH"		
02	"SIGNIFICANT WAV"		
03	"⊢E HT."		
04	AVIEW		
05	"E OR M?"		
06	AON		
07	TONE 2		
08	PROMPT		
09	AOFF		
10	ASTO Y		
11	CLA		
12	"E"		
13	ASTO X		
14	CLA		
15	X=Y?		
16	GTO 17		
17	"METRIC UNITS"		Simple Solution
18	AVIEW		
19	9.81		$\omega_{h_{max}} < 1.0$
20	GTO 18		
21	♦LBL 17		
22	"ENGLISH UNITS"		
23	AVIEW		
24	32.2		
25	♦LBL 18		
26	STO 06		$g \rightarrow R_{06}$
27	♦LBL 20		
28	"DEPTH?"		
29	TONE 3		
30	PROMPT		
31	"DEPTH="		
32	FS? 55		
33	XEQ 19		
34	STO 01		$d \rightarrow R_{01}$
35	"PEAK F?"		
36	TONE 4		
37	PROMPT		
38	"PEAK F="		
39	FS? 55		
40	XEQ 19		
41	STO 02		$f_p \rightarrow R_{02}$
42	4		
43	*		
44	PI		
45	*		
46	STO 03		$\omega_{max} = 2\pi(2 \cdot f_p) \rightarrow R_{03}$
47	RCL 02		
48	0.80		
49	*		
50	STO 04		$f_c \rightarrow R_{04}$
51	"ALPHA?"		
52	TONE 5		
53	PROMPT		
54	"ALPHA="		
55	FS? 55		
56	XEQ 19		
57	STO 05		$\alpha \rightarrow R_{05}$

STEP	KEY ENTRY	KEY CODE	COMMENTS
58	RCL 01		
59	RCL 06		
60	/		
61	SQRT		
62	RCL 03		
63	*		
64	STO 07		$\omega_{h_{max}} \rightarrow R_{07}$
65	1.0		
66	X<>Y		
67	X>Y?		$\omega_{h_{max}} > 1.0?$
68	GTO 02		
69	0.0081		
70	RCL 06		
71	*		
72	RCL 01		
73	*		
74	SQRT		
75	PI		
76	/		
77	RCL 04		
78	/		$H_\ell^* = \frac{(0.0081gh)^{1/2}}{\pi \cdot f_c}$
79	RCL 05		
80	0.0081		
81	/		
82	SQRT		
83	*		
84	STO 08		$H_\ell = H_\ell^* \left(\frac{\alpha}{0.0081}\right)^{1/2} \rightarrow R_{08}$
85	GTO 15		
86	♦LBL 02		
87	RCL 02		
88	2.0		
89	*		
90	STO 09		$2.0 f_p \rightarrow R_{09}$
91	RCL 04		
92	-		
93	4.0		
94	/		
95	STO 10		$dx \rightarrow R_{10}$
96	RCL 04		
97	STO 11		$f_c(i) \rightarrow R_{11}$
98	0.0		
99	STO 12		counter $\rightarrow R_{12}$
100	♦LBL 04		
101	1.0		
102	RCL 12		
103	+		
104	STO 12		counter $(i) \rightarrow R_{12}$
105	RCL 01		
106	RCL 06		
107	/		
108	SQRT		
109	RCL 11		
110	*		
111	2		
112	*		
113	PI		
114	*		
115	X↑2		

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STEP	KEY ENTRY	KEY CODE	COMMENTS
116	STO 13		$[\omega_h(i)]^2 \rightarrow R_{13}$
117	0.0		
118	STO 21		
119	1000.0		
120	STO 22		
121	10.0		
122	STO 20		
123	•LBL 05		
124	XEQ "CALC"		
125	1.01		
126	X<>Y		
127	X>Y?		ans. > 1.01 ?
128	GTO 06		
129	GTO 07		
130	•LBL 06		
131	RCL 20		
132	STO 22		
133	RCL 21		
134	+		
135	2		
136	/		
137	GTO 05		
138	•LBL 07		
139	0.99		
140	X<>Y		
141	X>Y?		ans. > 0.99 ?
142	GTO 08		
143	RCL 20		
144	STO 21		
145	RCL 22		
146	+		
147	2		
148	/		
149	GTO 05		
150	•LBL 08		
151	LASTX		
152	STO 14		$R(\omega_h(i)) \rightarrow R_{14}$
153	RCL 14		
154	RCL 13		
155	*		
156	2		
157	*		
158	STO 15		$[2(\omega_h)^2 R(\omega_h)](i) \rightarrow R_{15}$
159	XEQ "SINH"		
160	1/X		
161	RCL 15		
162	*		
163	1		
164	+		
165	1/X		
166	RCL 14		
167	X↑2		
168	1/X		
169	*		
170	STO 16		$\phi(\omega_h)(i) \rightarrow R_{16}$
171	RCL 11		
172	5.0		
173	Y↑X		
174	2		
175	PI		
176	*		
177	4.0		
178	Y↑X		
179	*		
180	1/X		
181	0.0081		
182	*		
183	RCL 06		
184	X↑2		
185	*		
186	RCL 16		
187	*		
188	STO 17		$\frac{(0.0081)g^2\phi(\omega_h)}{f(i)^5 (2\pi)^4} \rightarrow R_{17}$
189	RCL 12		
190	1.0		
191	X<>Y		
192	X=Y?		counter = 1.0?
193	GTO 10		
194	RCL 12		
195	5.0		
196	X<>Y		
197	X=Y?		counter = 5.0?
198	GTO 11		
199	RCL 12		
200	ENTER↑		
201	2		
202	MOD		
203	X=0?		
204	GTO 12		
205	RCL 17		
206	2		
207	*		
208	GTO 13		
209	•LBL 12		
210	RCL 17		
211	4		
212	*		
213	GTO 13		
214	•LBL 13		
215	RCL 18		
216	+		
217	STO 18		
218	RCL 11		
219	RCL 10		
220	+		
221	STO 11		$f(i)+dx \rightarrow R_{11}$
222	GTO 04		
223	•LBL 10		
224	RCL 17		
225	STO 18		
226	RCL 11		
227	RCL 10		
228	+		

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STEP	KEY ENTRY	KEY CODE	COMMENTS
229	STO 11		
230	GTO 04		
231	♦LBL 11		
232	RCL 18		
233	RCL 17		
234	+		
235	RCL 10		
236	*		
237	3		
238	/		
239	SQRT		
240	4		
241	*		
242	RCL 05		
243	0.0081		
244	/		
245	SQRT		
246	*		
247	STO 08		$H_\ell = H_\ell^{*}\left(\frac{d}{0.0081}\right)^{1/2} \to R_{08}$
248	GTO 15		
249	♦LBL "CALC"		
250	STO 20		
251	RCL 13		
252	*		
253	STO 30		
254	E↑X		
255	RCL 30		
256	CHS		
257	E↑X		
258	+		
259	STO 31		
260	RCL 30		
261	E↑X		
262	RCL 30		
263	CHS		
264	E↑X		
265	-		
266	RCL 31		
267	/		
268	RCL 20		
269	*		
270	RTN		
271	♦LBL "SINH"		
272	STO 32		
273	E↑X		
274	RCL 32		
275	CHS		
276	E↑X		
277	-		
278	2		
279			
280	RTN		
281	♦LBL 19		
282	PRA		
283	PRX		
284	RTN		

STEP	KEY ENTRY	KEY CODE	COMMENTS
285	♦LBL 15		
286	RCL 02		
287	Y↑2		$\bar{d} = \frac{h f_p^2}{g}$
288	RCL 01		
289	*		
290	RCL 06		
291	/		
292	-0.43642		
293	Y↑X		
294	0.02289		
295	*		
296	E↑X		
297	RCL 08		
298	*		$H_s = H_\ell \exp\left(0.02289\,\bar{d}^{-0.436}\right)$
299	"HS="		
300	ARCL X		
301	AVIEW		
302	TONE 6		
303	STOP		
304	GTO 20		
305	END		

107R-41CV-8

REFERENCES

Thompson, E. F., and Vincent, C. L. 1983. "Significant Wave Height for Shallow-Water Design," submitted for publication to The American Society of Civil Engineers.

U. S. Army Engineer Waterways Experiment Station, Coastal Engineering Research Center (CERC). 1984. Shore Protection Manual, revised edition in preparation, U. S. Government Printing Office, Washington, D. C.

Vincent, C. L. 1981. "A Method for Estimating Depth-Limited Wave Energy," Coastal Engineering Research Center Technical Aid 81-16, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Vincent, C. L. 1982. "Depth-Limited Significant Wave Height: A Spectral Approach," Coastal Engineering Research Center Technical Report 82-3, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Walton, T. L., Birkemeier, W. A., and Weggel, J. R. 1982. "Hand-Held Calculator Algorithms for Coastal Engineering," Coastal Engineering Research Center Technical Aid 82-1, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Miss.

APPENDIX A: BLANK PROGRAM FORMS

Program Description

Program Title		
Name		**Date**
Address		
City	State	Zip Code

Program Description, Equations, Variables, etc.

Operating Limits and Warnings

User Instructions

SIZE:

STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY

Program Listing

STEP	KEY ENTRY	KEY CODE	COMMENTS
001			
010			
020			
030			
040			
050			

STEP	KEY ENTRY	KEY CODE	COMMENTS
060			
070			
080			
090			
100			
110			

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS

DA
FILM
4